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A Joint Program with Japanese Investigators to Map Carbon II Line Emission from the Galaxy

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In collaboration with Prof. Okuda's team from ISAS, the Japanese Institute of Space and Astronautical Science, we have carried out an additional two balloon flights from the NSBF in Palestine, Texas during the summer of 1991. Both flights were successful and we completed a large area survey of [C II] line emission at 158 μ m from the inner galactic plane. The main scientific results are described in the attached preprint of a paper entitled "GALACTIC PLANE SURVEY OF [C II] 158 mm LINE EMISSION" by Low et. al. This paper will appear in the Proceedings of the Neugebauer Symposium to be published by PASP.

GALACTIC PLANE SURVEY OF [C II] 158 μ m LINE EMISSION

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ABSTRACT A large portion of the inner galactic plane has been mapped in the far-infrared [C II] line using a balloon borne survey instrument. Complete coverage is reported from 25 degrees north to 80 degrees south of the galactic center and extending a few degrees on each side of the plane. Effective resolution is 14.1 arcmin (FWHM) and contour levels begin at 2×10^{-5} ergs $s^{-1} cm^{-2} ster^{-1}$. When compared with 100 μ m dust emission observed by IRAS the [C II] appears well correlated with the dust emission except for a 10 degree region centered on the galactic center where emission from the gas is much weaker than that from the dust.

INTRODUCTION

Because [C II] line emission is the major cooling line for interstellar gas (Tielens and Hollenbach 1985) and because the line offers unique opportunities to study otherwise inaccessible aspects of the interstellar medium it has become an important addition to our astrophysical tools. Our group, which combines resources from two countries, has carried out five successful balloon flights using two different instruments. Here we report very briefly on our most recent large area survey observations of the inner galactic plane.

Observations made from a single balloon flight originating in Palestine Texas have been combined with those made on a flight in May 1992 from Alice Springs, Australia. On both flights the same instrument was used in order to obtain complete and relatively uniform coverage of the inner galactic plane. The map reported here is preliminary in nature since the southern coverage is based on preliminary data reductions.

Improvements in absolute calibration and signal-to-noise may still be expected but only small changes in the main features should result.

These new results were obtained with an instrument designed specifically for large area surveys. Nakagawa (1992) describes this system in more detail than will be given here and he also describes an earlier instrument, *BIRT*. Table 1 lists the dates, locations and principle results of all five successful balloon flights with these two instruments. Our success rate for balloon flights originating at the balloon facility in Palestine, Texas is noteworthy, 4/4, while only the last of three flights attempted in Australia proved successful.

TABLE I Observation Log

INSTRUMENT	DATE (SITE)	DURATION	OBJECTS
BIRT	1988.5.25 (Palestine)	7 hr	G. C. NGC6334
BIRT	1988.6.05 (Palestine)	9	G. C., M17 G-Plane
BICE	1991.5.26 (Palestine)	12	G-Plane ρ-Oph
BICE	1991.6.12 (Palestine)	8	G-Plane ρ-Oph, Cyg-X
BICE	1992.5.24 (Alice Springs)	10	G-Plane LMC

Our new balloon survey results may be compared with our earlier results (Shibai et al. 1990, 1991), with many [C II] observations from the Kuiper Airborne Observatory (KAO) and, most recently, with results from the FIRAS instrument on COBE (Wright et al, 1992). Each of these observing platforms and their instruments emphasize different observational capabilities; COBE provided global coverage at very broad spatial resolution while the KAO yields the highest spatial resolution. Our balloon instrument is complementary since large areas can be mapped with the spatial resolution needed to resolve bright sources of emission from the underlying extended emission.

INSTRUMENTAL DETAILS

Table 2 gives the most important details of the survey instrument known as the *Balloon-borne Infrared Carbon Explorer (BICE)*. Only a single high performance stressed Ge:Ga detector was used but excellent sensitivity, $\text{NESB} \sim 1 \text{ E} -12 \text{ w cm}^{-2} \text{ ster}^{-1} \text{ Hz}^{-0.5}$, and a rapid survey rate were achieved. Emissivity of the telescope is $<3\%$ and the detector system is background limited. The mode of operation developed for the survey was to linearly scan the cooled Fabry-Perot spectrometer at a rate of 5 Hz through the $158 \mu\text{m}$ line while scanning the sky in azimuth at fixed elevations. The elevation was gradually changed to maintain a raster pattern centered on the galactic plane. Though out these flights the azimuthal stabilization system and absolute pointing were accurate to much less than a beam width.

TABLE 2 System Parameters for BICE

Telescope	Off-axis Newtonian
Aperture	$35 \text{ cm} (20 \text{ cm})^1$
Spatial Resolution	12.4 arcmin
Spectrometer	Fabry-Perot
Center Wavelength	$157.741 \mu\text{m}$
Velocity Range	520 km s^{-1}
Spectral Resolution	1800
System NEP	$1 \text{ E} -15 \text{ w Hz}^{-0.5}$

¹⁾ The physical size is 35 cm, effective size 20 cm.

By scanning 260 km/sec on each side of the line and by sampling 12 times in each scan we obtained useful velocity information and we were assured of measuring total intensity in the presence of significant variations in velocity. Absolute surface brightness calibration is based on independent studies of the bright source M17, which was observed on each flight.

OBSERVATIONS

Figure 1 shows the map made by combining results from the northern and southern hemispheres. The contours represent the integrated intensity and their levels are $0.2, 0.7, 1.5, 2.5, 4, 6, 9$, and $12 \text{ E}^{-4} \text{ ergs s}^{-1} \text{ cm}^{-2} \text{ ster}^{-1}$. Because the map is based partly on preliminary data reductions, the uncertainty in intensity is as large as 35% in portions of the map. Note that the effective resolution in this map is 14.1 arcmin (FWHM) while the beam size was 12.4 arcmin (FWHM).

This is because the scans were smoothed with a 9 x 9 arcmin rectangular filter before the map was constructed.

INTERPRETATION

Using the 100 μm IRAS data we have constructed a map of dust emission with the same spatial resolution and extent as the [C II] map shown in Figure 1. When these two maps are compared the following preliminary conclusions can be reached.

1. Away from the galactic center, the size, location and intensity of the brightest sources in the two maps appear to be surprisingly well correlated. Furthermore, the gas-to-dust ratio, measured on this broad scale, is roughly consistent from cloud to cloud and throughout the intervening background.
2. Within 5 degrees of the galactic center the ratio of [C II] emission to 100 μm emission changes significantly. At our spatial resolution the [C II] emission is relatively weak compared to dust emission in this inner region of the galaxy.

Inspection of Figure 1 shows that the background immediately surrounding the central source at the galactic center appears weaker relative to typical areas further from the center. Since we can find no reason for observational errors that would produce this effect we believe it is real.

E. L. Wright remarks that a similar effect is seen in the COBE observations of this region and he has suggested self absorption as a possible explanation. We do not yet understand in detail the complex ways in which the gas is ionized and heated by the interstellar radiation field in and around massive clouds or in the intervening medium. Therefore, we suggest that other explanations should be considered. It seems possible that the higher densities of gas and associated dust near the galactic center may reduce the illumination of the individual volumes in which the [C II] emission is produced.

In conclusion, many new quantitative data are now becoming available for more detailed study of physical conditions in poorly understood parts of the interstellar medium.

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